HAWAII AGRICULTURAL EXPERIMENT STATION

HONOLULU, HAWAII

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GRAFTING TROPICAL FRUIT TREES IN HAWAII

BY

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and

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TABLE OF CONTENTS

INTRODUCTION

In the Hawaiian Islands the principal fruit crops are best propagated by vegetative methods rather than by seeds, as is the practice with such crops as wheat, corn, rye, barley, cotton, flax, etc. Most of the standard crops of Hawaii are easily propagated by vegetative methods, but they are difficult of propagation by seed. For instance, the improved sugar-cane varieties are all propagated from cuttings which trace back in each instance to the original mother plant, presumably a seedling that possesses certain desired characteristics. The extensive pineapple plantings, aggregating many thousands of acres, are composed almost exclusively of Smooth Cayenne plants which have been propagated from slips, suckers and crowns tracing back to the original Smooth Cayenne pineapple plant developed many years ago. The different varieties of taro are propagated by transplanting the "hulis"[1] and offsets detached from the mother plant. Bananas are grown from the suckers which develop around the base of the mother

[1] A "huli" is the upper portion of the taro root containing the crown bud used in vegetative propagation.

plant. Crops may be matured from any of these crops in from one to two years, whereas it would take much longer to produce bearing seedlings from the crops in question. The great advantage of vegetative propagation, other than the ease of propagation, is the fact that each resulting plant is normally exactly like the mother plant as regards the crop produced. This makes for uniformity of product, which is a most important consideration as regards either marketing or manufacture.

Some fruit trees, such as figs, may be propagated from cuttings, but most of the fruit and nut trees require budding or grafting, which is a more complicated method of vegetative propagation requiring certain precautions and considerable skill on the part of the operator. For instance, there are at the present time hundreds of different seedling avocado trees in Hawaii. No two of these trees bear fruit exactly alike. It is very difficult to establish a dependable market for avocados which are all so different one from another. In California, the avocado producers have organized and are attempting to discard all but a very few of the best varieties as it is realized that the market demands a reasonably uniform, dependable product. Hawaii should do the same with her tree fruits. This can be accomplished by deciding on a very few of the best varieties and topworking all the other trees with graftwood from the selected varieties. All future trees should be seedling trees which, while young, have been budded or grafted with wood from the standard varieties. Not only will the grafted small seedlings produce fruit several years earlier than if left ungrafted, but the resulting fruit will be of the same good sort as the tree from which the graftwood was taken. It is also possible to use seedling trees which have a very vigorous root system, resistant to plant diseases and other adverse conditions, and that is oftentimes superior to the root system possessed by the parent tree of the desired variety from which graftwood is obtained.

VEGETATIVE PROPAGATION

Grafting is the most satisfactory method of vegetative propagation of the leading kinds of fruit trees in Hawaii. One form or another of graft union has been successfully employed in the propagation of the various kinds of citrus, avocado,

mango, Macadamia nut, coffee, litchi and lungan. The last two mentioned have proven the most difficult to graft, for which reason an old method of vegetative propagation is still most satisfactorily employed.

With all forms of grafting, the union takes place best when the growth of the propagating material is most vigorous. The more intimate the contact of the cambium parts brought together, and the less injury their cells sustain in adjusting them, the more likely they are to unite. Grafting, of which budding is a form, can only be accomplished with plants of exogenous growth as in this kind of structure the cambium forms a complete cylindrical layer around the stem of wood beneath the bark. Plants such as grasses and palms do not have this cambium ring and consequently cannot be successfully grafted.

There are two parts of a graft,—the stock and the scion. (Fig. 1, a.) The stock is the basal part,—the stem of the plant, or possibly a branch or trunk of a tree on which the scion is grafted. When the stocks consist of small plants, they are usually called rootstocks. The scion is a piece of twig or shoot cut from a plant for use in grafting. The piece may contain a single bud or several buds.

The form of graft union varies greatly according to the nature of wood used. Most grafting is done by uniting young scions on young seedling rootstocks. When scions are united with branches or the trunk of a tree, the grafting is called topworking.

Growing and Selection of Stocks and Scions for Grafting

One of the most important parts of the entire operation is the selection of the scions which should be in a healthy, vigorous condition of growth. The possibility of such a condition depends largely upon the season. The best scions are the firm, delicate growth of the current year. Wood of the previous season, that is, 2 years old, is sometimes used successfully, but the buds of such wood are usually in a dormant condition. Scions should be taken from healthy trees of the best available varieties.

In grafting, the union usually takes place best when both the stock and scion are vigorous and in an aseptic condition. The flush or sudden start of growth, desired in newly grafted plants may be stimulated by the use of nitrate of soda fertili-

zer dissolved in water at the rate of one ounce to the gallon. A pint of this liquid fertilizer applied at one time is sufficient for each seedling that is to be grafted. The application should be made about 10 days before the grafting is to be done. The orchard trees, from which the scions of desired variety are to be taken, may also be stimulated with nitrate of soda fertilizer applied at the rate of one pound to each tree of medium size. This should be applied at about 3 weeks before cutting the scions.

In the budding and grafting of young nursery stock, the production of healthy seedling rootstocks is of great importance. Seeds should be selected of a vigorous variety, and as far as possible, should be of such stock as will be adapted to the soil where the grafted trees are to be planted. They should be germinated in clean coral sand which has been rinsed with fresh water to remove saltiness. For seeds of avocados, mangoes, and Macadamia nuts, the propagating box should be about 12 inches deep and the seeds planted about 2 inches apart and about the same depth below the surface; the soil should then be pressed down firmly over the seed. The box should be kept in the bright sunlight, which will make the plants strong and of great stem diameter. They should also be liberally watered about 3 or 4 times a week, and in about 2 or 3 weeks, the seedlings will be up. When they are 6 or 8 inches high, they should be taken up and set in 7-inch plant pots or gallon tin containers of rich garden soil. Care should be taken that these containers have good bottom drainage. If the taproots have reached the bottom of the propagating box at the time of transplanting, they should be clipped off at about halfway up to the seed as they will have practically no further function, if the plants are given sufficient moisture. When the stems begin to get slightly woody but still greenish in color of bark and have diameters of about $\frac{3}{8}$ inch or a little more, they are ready for grafting. To reach this condition of growth usually requires from 4 to 6 weeks after transplanting to the containers. During this time, the seedlings should be kept growing in the strong sunlight out-of-doors, and the containers kept far enough apart to prevent the plants from becoming tall and spindling. When the stock and scion are in fairly good condition, they will unite easily by one or more of the several forms of graft union.

The method of growing seedlings and grafting them while in tin containers has been practiced at the Hawaii Experiment Station on account of the unsatisfactory soil conditions for field nursery work.

Making the Graft

In making the graft union, the cut surfaces are made with a clean, sharp knife, as it is important that the delicate juicy cells of the cambium layer of both stock and scion should be disturbed as little as possible. When grafting, the operator should work as rapidly as is consistent with good work so that the cut surfaces will dry as little as possible. Place stock and scion together and bind the union firmly with raffia fiber [2] or cotton twine. The inner bark of the hau tree (*Hibiscus tiliaceus*) may also be used. The former is best, as it tends to form a flattened band which is less apt to indent the growing bark during the few weeks following, when the tissues of the stock and scion are uniting. The union need not be entirely covered by the string, but the firmness is important. After a number of grafts have been made, melt ½ teacup of paraffin, which, when cool enough to test with the finger without burning, should be applied with a brush, forming a thin transparent coat over the entire scion and union. A paraffin coating offers several advantages over such other coverings as wax tape and grafting wax, which are also used for this purpose. It is easy to apply and is better adapted to filling in cracks and crevices than are the harder waxes; it is clean, waterproof, durable and inexpensive; it allows a natural action of light upon the green tissue; and it prevents excessive evaporation and the entry of any foreign matter. The paraffin is also easily pushed off by the growing bud, but this is at such time when it is of no further use.

The pots or tin cans containing the newly grafted plants are set in a cool, shady place sheltered by other larger plants which tend to maintain the humid atmosphere desirable until the scions have put forth several small leaves. It is at this time that they may be removed to a place of more light and air for further growth and where they remain until well established and ready to be taken into the open sunlight. If

[2] Raffia is the name of a certain palm, the leaves of which furnish fibrous strings, useful in many ways.

the buds form unnecessary branches during this latter growth, they should be pinched off so as to force the one main shoot into greater vigor and upright form. The main stem is allowed to grow leaves as a protection to its green bark against sunburn until it has developed a mature gray bark, which is usually formed before the plant has been set in permanent place. As soon as the scion indicates that the union is well united, the binding material may be carefully cut so as to allow the bark to expand and grow normally.

The trees should be transplanted to their permanent locations just as soon as they become sufficiently hardened after grafting. If they remain too long in the containers, they will become root-bound, a condition from which it is hard for them to recover. The plants should be set in the ground in less than a year from the time the seedlings were potted, if possible.

Forms of Graft

Whip graft.—This form of graft is made by cutting the stock off at an angle, giving a beveled surface of about 1½ inches in length. On this surface a wedge-shaped tongue ¾ inch long is cut to receive a similar tongue made in the beveled surface of the basal end of the scion. (Fig. 1, a.) The two parts are put together, tied, and given conditions as described under the subheading "Making the Graft." This form of graft has proven very satisfactory for the avocado and citrus. (Fig. 3.)

Cleft graft.—(Fig. 1, b and b[1]). This form is sometimes called the wedge graft. It is very satisfactory for young nursery stock of both avocado and citrus. The seedling stock is cut squarely off at about 3 to 5 inches from the soil and the remaining stub split down through the middle for 1½ or 2 inches to receive the wedge-shaped basal end of the scion. The split surface may be beveled off to receive a broader wedge of the scion and to give a better shaped union, as is shown in Figure 1, b[1]. Further treatment of the cleft-grafted seedlings is described under the sub-heading "Making the Graft."

Side-tongue graft.—This method of grafting seedling rootstocks has some advantages which seem to give much better results than do the other methods with certain kinds of trees, particularly the mango and the Macadamia nut. In this form of graft (Fig 1, c) the top of the seedling is retained for

several weeks, that is, until the scion has made a fairly good growth. At the time of making the graft, the terminal bud of the seedling is usually clipped off to retard the upward growth, but the old foliage is allowed to remain. (Fig. 1, c.)

In making the side-tongue union, the seedlings, if in containers, are brought into a well-lighted, sheltered place and placed upon a work-table of convenient height for the operator. The point for the graft is selected at such distance above the soil as to be convenient for the work; this distance usually ranges from 4 to 7 inches. The knife blade is sharpened and then thoroughly cleaned by dipping it in alcohol and wiping it with a clean cotton cloth. The cut surface is made 2 or 2½ inches long, smoothed off so that when united with this scion, it will fit perfectly. (Fig. 4.) The edge of the cut surfaces should not be bruised. Tongues are cut in the beveled surfaces of both stock and scion so as to aid in holding the parts together while being tied and also to afford greater surface for the uniting of the cambium layers. The union is then bound firmly with a strip of moist raffia, which tends to tighten slightly as it dries. The whole outer surface of the union, including the tying material and the entire surface of the scion, should be protected from outside contamination by a coat of paraffin.

The grafted trees are then set aside in a comparatively cool and properly shaded place until growth of the scions begins. At the end of a few weeks, when they have made considerable growth, and have fairly mature leaves, the seedling tops are cut off at an angle just above the union, leaving the growing scions to receive all of the crude sap from the roots and to form the entire top of the desired variety.

Bark graft.—(Fig. 1, d and d[1]). This form of graft has been found very satisfactory for citrus at the Hawaii Experiment Station. The seedling rootstock is clipped off at a slight angle about 4 inches above ground and, beginning at the higher side of the stub, the bark is split down for about 2 inches, as indicated below the dotted line in the figure. (Fig. 1, d.) The scion is beveled off at the base from one side for 2 or 2½ inches. It is slipped down between the bark and the wood, beginning at the point where the bark is split so that the cambium of the two surfaces will be in contact. It is then tied, paraffined, and kept under the same conditions as in the other forms of grafts discussed. (Fig. 1, d[1].)

Shield budding.—Shield budding is performed only on young nursery stock or on the smaller branches of trees in which the sap is flowing and the bark separates easily from the wood. It is not usually employed where the diameter of the stock exceeds an inch. (Fig. 1, f and f^1.) Budding may be employed when there is a scarcity of scionwood or in cases where the operator finds this method more convenient or more to his liking.

The first step in the operation is the cutting of a T-shaped incision on the stock, preferably on a long, smooth internode. The cut should be about an inch in length and should be only into the bark as far as the wood. The triangular flaps at the top of the incision are slightly loosened so that the bud may be easily slipped beneath them.

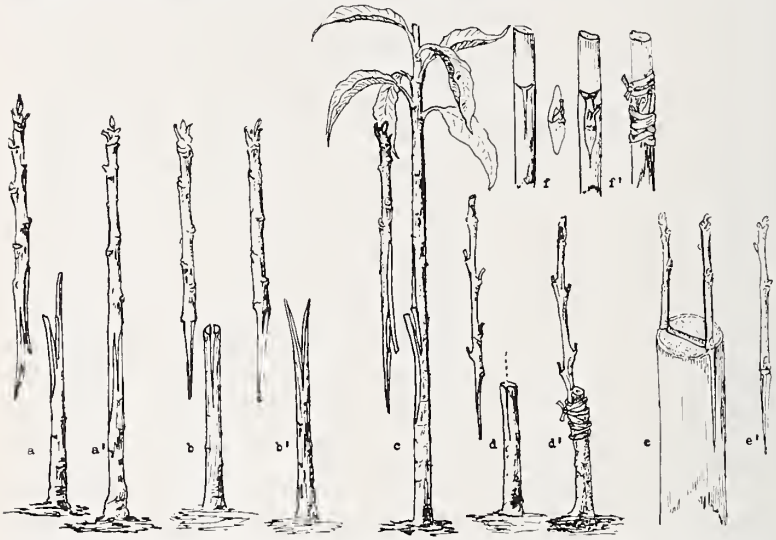

FIGURE 1.—Forms of union of the stock and scion in grafting and budding:—**a** and a^1, the whip graft; **b** and b^1, two kinds of cleft; **c**, side-tongue; **d** and d^1, bark graft; e and e^1, cleft graft as employed in top-grafting trees; and **f** and f^1, the bud union.

A suitable bud is selected and is sliced from the scion-wood with a sharp knife. The length of the "bud" should equal that of the incision. The end of this "bud" is next put under the flaps of the incision and the whole slid into place. It is then tied tightly with raffia, after which operation it is waxed, leaving only the bud itself exposed, or it may be bound with

nurserymen's tape and set aside without waxing. Paraffin coverings are not used in shield budding.

Where the current year's growth is used as budwood, a portion of each leaf-stalk is left below the bud. If, in about 10 days, this leaf-stalk falls off it is a good indication that a union has taken place, whereas if the leaf-stalk fails to fall when given a gentle touch, the indication is that the bud has died.

In about two weeks' time there should be a union and the raffia may be slit on the side of the stock opposite the bud or the tape may be removed to prevent girdling. No further attention is necessary until growth has started, when the top of the stock is cut back to the bud and the exposed surface sealed with wax.

Topworking.—Topworking is employed where it is desired to graft a large seedling tree with budwood of a superior variety. In cases where the tree is too large to conveniently graft the branches, it is cut down almost to the ground and the sucker shoots that arise are grafted or budded. When the suckers are still young and of small diameter, the side-tongue graft or shield bud may be used. If the suckers have been allowed to grow too large, cleft-grafting is employed with a scion at each of the outer extremities of the cleft. This method is also practiced where the trees are not too large and where it is possible to graft each of the larger individual branches. The grafting should be done in the main framework branches, going back in each case to as near the center of the tree as is possible without being forced to use too large a limb. Only about half of the branches are grafted at a time, the others remaining to provide for the grafts. In cases where the grafts cannot be shaded by branches, the scions may be protected by inflated paper bags of 10- or 12-pound capacity tied over each union in an inverted position. Ventilation may be provided by making a few half-inch holes in the sides of the bags. These paper bags are allowed to remain until growth begins.

Methods of topworking mature avocado trees, as practiced to considerable extent in California, are given in full in "Agricultural Notes," No. 28 (August, 1932), Agricultural Extension Service, University of Hawaii, Honolulu, Hawaii.

Grafting Tools and Supplies

The necessary tools for grafting and budding are not numerous, but are of considerable importance to the work. The several kinds of knives found useful should be of good quality both in material and workmanship. The blades of both the grafting and budding knives (Fig. 2, f and e) should be comparatively thin and well riveted into the handles. The budding knife, in particular, should have the rivet, on which the blade hinges, set in metal ends of the handle, otherwise it will soon become loose and unsuitable for skillful work. While

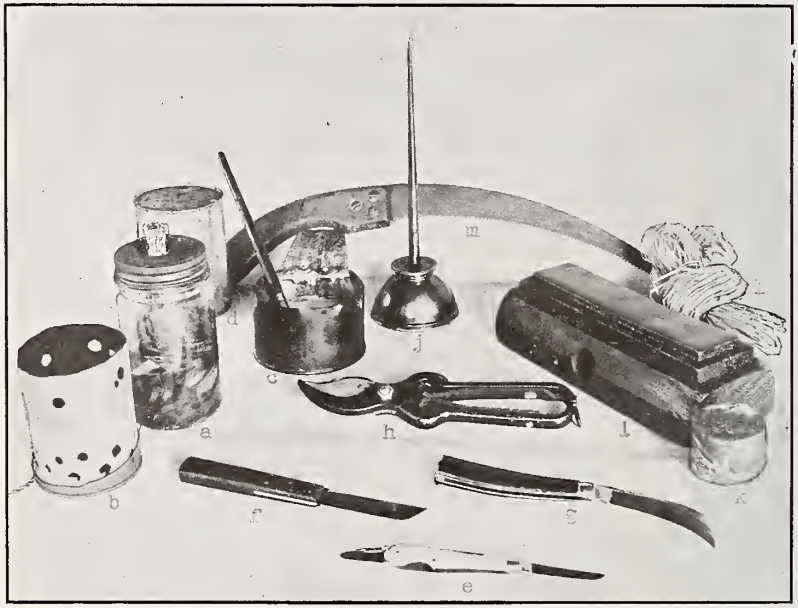

FIGURE 2.—Tools used in budding and grafting: Parts of alcohol lamp for melting paraffin, a, **b**, **c** and **d**; a, bowl and burner; **b**, flue for providing the draft; **c**, cup for paraffin; **d**, flame extinguisher; e, budding knife; **f**, grafting knife; **g**, pruning knife; **h**, hand-pruning shears; **i**, whetstone; **j**, can of whetstone oil; **k**, grafting wax; **l**, raffia; **m**, saw for removing branches in top-work and air-layering.

grafting or budding, a good whetstone and a small can of whetstone oil should be kept close at hand for use in keeping a sharp, smooth edge on the knife. (Fig. 2, i and j.) A good pair of hand pruning shears, about 9 or 10 inches long, is a

great convenience for cutting the graftwood, removing the tops of the seedling in cleft and bark grafting, as well as for the removal of tops of seedling nursery stocks after the scions have taken, particularly where the side-tongue union has been employed. The small pruning saw (Fig. 2, m) is a convenience for cutting back branches in topworking, and it is particularly useful for removing air-layered branches from the parent tree. The grafting wax is useful as a permanent covering for wounds, particularly those left just above the graft union where the seedling top has been removed. Raffia (Fig. 2, l) is an excellent tying fiber which most horticulturists prefer above all other tying materials. The alcohol burner, used for melting paraffin, is simple in construction. It consists of four parts, as shown in Figure 2, a, b, c and d. The bowl for the denatured alcohol consists of a glass fruit jar with a hole made in the metal cap to receive the wick. The flue is made of a small can with both top and bottom cut out, a few holes punched in the sides to permit the entry of air, and a wire handle, as shown in Figure 2, b. The small cup (this also the bottom section of a can), holds the paraffin while melting, and the extinguisher (Fig. 2, d) from putting out the flame after paraffin and the flue are removed.

Grafting wax.—Several kinds of grafting wax and other healing preparations used in grafting and for covering tree wounds are described by Professor L. H. Bailey in the Farm and Garden Rule Book, published by Macmillan Co., New York, 1911.

The following recipe has proven very satisfactory in making a grafting wax suitable for use in covering exposed surfaces after the tying material has been removed from the graft union.

RECIPE

Tallow	1 part by weight
Beeswax	8 parts by weight
Resin	4 parts by weight

Place tallow and beeswax in a suitable pot and melt over slow fire. When mixture is brought near to boiling, add the resin, a little at a time, stirring continuously until resin is melted. Boil for 5 minutes longer, then remove from fire and pour boiling mixture into container of cold water. When the

wax is sufficiently cooled, it is removed and kneaded, worked over and pulled until thoroughly cooled. If the wax adheres to the hands, the hands should be slightly rubbed with a little melted tallow. As soon as the wax assumes a creamy, silken color it can be worked into rolls, 4 or 5 inches long and 1 or 2 inches thick, and wrapped in oil paper for future use. (Fig. 2, k.)

AVOCADO PROPAGATION

For many years the avocado has been propagated mainly by seeds in Hawaii. Certain seedlings having fruit of unusual qualities have occasionally furnished the scionwood for propagation by inarching, budding and grafting.

FIGURE 3.—Grafting avocado nursery stock; left to right:—(1) The seedling stock; (2) Whip graft; (3) Scion developing leaves; and (4) The grafted tree of desired variety ready for transplanting in permanent place.

In producing a few trees for the home lot, seedlings have proved fairly satisfactory as avocado seedlings from good fruits usually produce fruit of quite desirable characteristics. With increased interest in recent years, new varieties and

choice hybrids have been developed. The importance of budding and grafting, when commercial orchards are to be established, has now become fully recognized. The Hawaii Experiment Station has experimented with numerous methods of budding and grafting for a number of years, but only the easiest and most successful methods are described in this publication.

Young grafted avocado trees usually come into bearing from 1 to 3 years earlier than do the seedling trees. This, together with the fact that one is sure of getting exactly the kind of fruit he wants if a grafted tree is set out, causes grafted trees to be greatly preferred by most growers.

The propagation and culture of the seedlings for rootstocks, and the collection of the scionwood, are described under the sub-heading of "Growing and Selection of Stocks and Scions for Grafting." Young avocado seedlings, properly grown, are usually ready to graft by the whip and cleft graft methods (Fig. 1, a and b) in from 50 to 120 days from the planting of the seeds for germination. (Fig. 3.) For older seedlings (up to a year or 18 months old) the side-tongue graft union is the best. (Fig. 1, c.) In this case, the top of the seedlings should not be cut off until the scions have made a substantial growth.

Methods of budding adapted to the avocado are described under the sub-heading "Shield budding."

CITRUS PROPAGATION

Citrus fruits grown in Hawaii consist of varieties of oranges, pummelos, grapefruit, mandarins, lemons and limes. These are propagated by seeds and by budding and grafting. The cultivation of seedlings is rapidly being abandoned as the majority of such trees tend to be either poor bearers or produce fruit of poor quality as to size, flavor, and with unusually large numbers of seeds. Most all of these undesirable qualities may be avoided by grafting or some other form of vegetative propagation, using scionwood of one variety or another known to be vigorous, prolific, early bearing, and of good quality. With citrus, the most successful methods are grafting and budding. Experiments with both these methods, as well as inarching and propagation by cuttings, have been in progress for years at the Hawaii Experiment Station. The

best success has been experienced in grafting 10- or 12-month old seedling nursery stock by either the whip, cleft or bark grafts (Fig. 1, a, b and d).

Seedling rootstocks of sour orange and pummelo of the shaddock type have been found vigorous and more or less resistant to gum disease or "gummosis," which, in many citrus-growing countries, is the worst enemy of citrus trees of most species. The rootstocks are grown from seeds taken from selected fruit, washed, and planted without much delay.[3] The germinating medium should be a light soil or clean coral sand, which is best handled in shallow boxes having narrow cracks in the bottom for drainage. Germinating boxes are about 14 inches by 18 inches by 4 inches deep. The sand is rinsed with fresh water to wash away any saltiness it may contain. It is then placed in the box and firmed down to a surface ¾ inch below the top edges of the box. The seeds are then scattered at about an inch apart and covered with ½ inch of sand gently packed. The box is then labeled,—giving name and date of planting, and placed in a fairly good light and with the ordinary warmth and moisture of common Hawaiian conditions.

The seedlings will be up in a few weeks and when about 2 inches high, they should be transplanted to individual containers; 3½-inch plant pots are most suitable, and the soil should be a rich, sandy loam. It is not advisable to put the seedlings in large containers when small, but after 6 or 8 weeks, they should be transferred to larger containers about 8 inches in diameter and having a capacity sufficient for their growth until, as grafted trees, they are ready to be set in permanent place. In these conditions the seedlings are of suitable size for grafting in 6 or 8 months.

At the Hawaii Experiment Station the best results have been obtained with the bark graft unions, (Fig. 1, d and d[1]). Scionwood should be selected of firm, healthy green growth, preferably of the current year. This wood is in the best con-

[3] The drying of citrus seeds in the sun or for considerable time tends to toughen the seed coats and consequently prevents germination or causes serious delay and a deformity of rootcrown, which is well-known to nurserymen as "Z-root" or "bench root." Professor J. E. Coit and other citrus writers describe bench root, stating that the Z-shaped kink develops in the sprouting caulicle, extends into the upper portion of the root system, preventing the possibility of formation of a good root system, and stunting the growth of the seedling to such an extent that it may never fully recover.

dition about a month previous to the time of blossoming. As soon as collected, the leaves should be cut off without injuring the buds, and the scions packed in damp moss and wrapped in wax paper. In making the graft, the bark union is simple and this form allows for considerable difference in diameter of stock and scion. The bark graft union is then made as described under that heading and illustrated in Figure 1, d and d^1. The care to be given following the operation is also discussed under the sub-heading "Making the Graft."

COFFEE PROPAGATION

Coffee is propagated mainly by seeds in Hawaii. The plants also may be propagated by grafting. This can be done with nursery stock or by topworking young or fully grown trees. Although the seedling crops are fair, there is a certain amount of variation in the crops, as well as in the habit of growth, which cannot be overcome except by some form of vegetative propagation. The varieties should be standardized for the best results.

In grafting, the scions must be taken from upright branches. These have the same function as the main stem or trunk of the tree. Upright branches do not produce fruit, but produce lateral branches which do bear fruit. Lateral branches, when propagated vegetatively, will not make coffee trees. Cuttings made from upright branches root easily and produce entirely normal trees. Both cuttings and graftwood of upright branches should be of mature growth, that is, past the green stage. Although it is possible to increase coffee plants in considerable numbers by cuttings, it is an unsatisfactory method for propagating either improved hybrids or the several well-known seedling varieties that have long been in local cultivation and are known to have comparatively weak and non-resistant root systems. For this reason, grafting is a more desirable practice, particularly in the development of nursery stock with root systems resistant to nematodes, adverse conditions, etc.

Experiments are in progress at the Hawaii Experiment Station in which nursery stocks of the varieties of Arabian coffee are being grafted upon vigorous and resistant rootstocks of the Liberian and Robusta varieties. The forms of union employed are the whip, cleft and side-tongue grafts. (Fig. 1.)

The object of these experiments is to get the desired varieties standardized and established on vigorous rootstocks resistant to adverse conditions, and with a uniformity that will facilitate fertilizer experimentation and commercial exploitation.

MACADAMIA NUT PROPAGATION

For many years the Macadamia nut has been propagated by seeds in Hawaii. Since the nut has shown considerable promise as a commercial crop, standardization appears necessary. The Hawaii Experiment Station began vegetative propagating experiments a number of years ago, and after a reasonable degree of success, Bulletin No. 59, "The Macadamia Nut in Hawaii" was published in 1929. In addition to the history and general culture of this nut in Hawaii, considerable discussion was devoted to propagation, both by seeds and vegetatively.

It has been found highly important to make careful seed selection in producing trees for planting and in growing rootstocks for grafting. In the latter, only vigorous seedlings should be selected. Both air-layering and inarching have proven too slow and inconvenient for most needs. Cuttings tried in different mediums, both in the propagating house and outside, gave very unsatisfactory results. A few days after being set, they tend to develop green shoots and foliage, but this growth soon slows down and in most cases the cuttings die without the formation of roots at the bases. This is an indication of too much heat above and too little heat below, a well-known occurrence which long ago brought about the development of the propagating bench with bottom heat sufficient to maintain a soil of proper warmth at a time when the air above is comparatively cool. Such a condition first starts the chemical change of the stored plant food in the cambium at the basal ends of the cuttings, and small roots are formed and begin absorption of food from the soil in advance of the leaf shoots which naturally develop on the stem above the ground.

In Macadamia grafting experiments at the Hawaii Experiment Station, a number of kinds of grafts have been tried. The side-tongue graft has given the largest percentage of success, and in most cases has proven the best form of union. Topworking young trees, 2 to 4 years old, has also been successfully accomplished.

In making the side-tongue graft of Macadamia-nut nursery stock (Fig. 4), both scion and stem of the rootstock should be of about the same size and vigor. At this age (2 to 4 years), propagating material usually varies from 5/16 to ½ inch in diameter. The seedlings are propagated as described under the sub-heading "Growing and Selection of Stocks and Scions for Grafting." Particular attention, however, should be given to the selection of seed from vigorous trees, and in the germination, investigation has indicated that the position in which the seeds lie in the sand is not necessarily the cause for crooked root crowns. Copious watering during the first 10 days after planting is important so that the shell may absorb sufficient moisture to open freely in germination. The same result may also be obtained by using a medium of one-half coral sand and one-half coarse leaf mould. The latter increases the water-holding capacity sufficient for rapid absorption by the hard shell. The wood of the Macadamia is rather hard and requires a strong, sharp knife for making the union, otherwise the union is made as described under the sub-heading "Side-Tongue Graft."

MANGO PROPAGATION

The mango is a common dooryard tree in Hawaii. Although the fruit is common on the local markets, it is not grown on a large commercial scale. There are many varieties which are propagated vegetatively by inarching, budding and grafting. Old seedling trees occasionally have their tops worked over to desirable varieties by grafting, but the practice is not common.

The best method worked out for vegetative propagation of nursery stock of the mango at the Hawaii Experiment Station has been the grafting of 10-month old seedlings by the side-tongue graft union. (Fig. 1, c and Fig. 4.) On a number of occasions, different workmen at the Hawaii Experiment Station have been successful in getting as high as a one-hundred per cent of successful grafts with considerable numbers by this method. The seedlings are raised as previously described; however, it is important to state that a more rapid germination of seed is accomplished by removing the seed coat or husk from the seed. This is done by removing the seed from

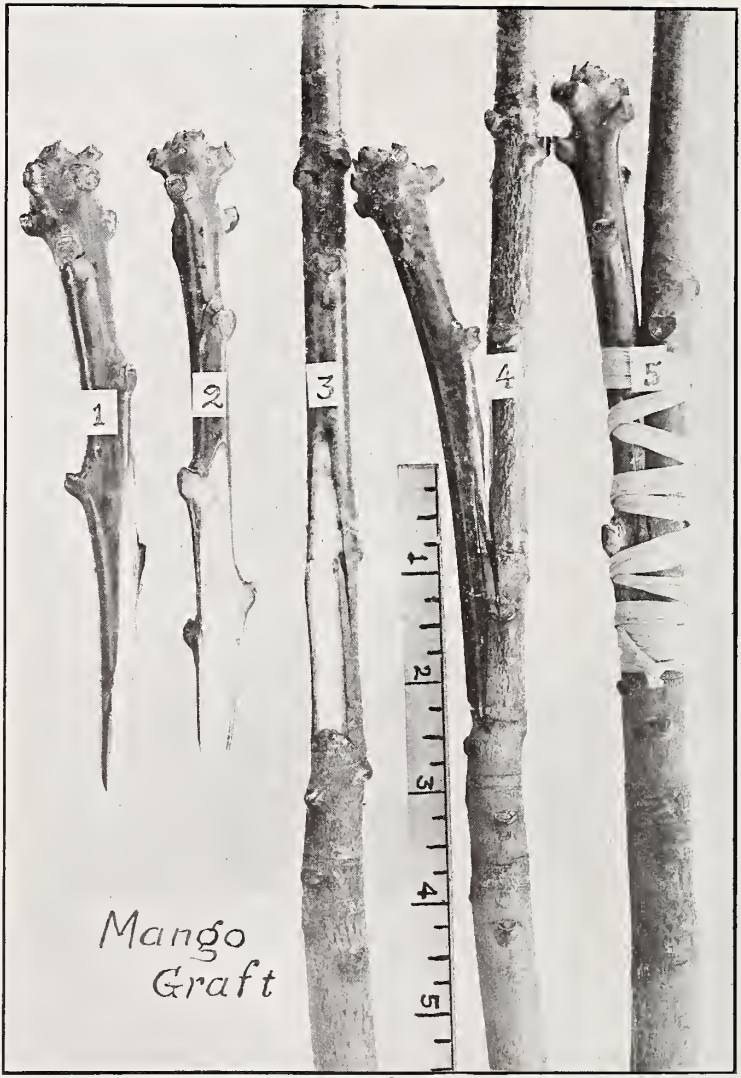

FIGURE 4.—Side-tongue graft as employed with the mango and the Macadamia nut: (1) Six-inch scion showing first cut in making union; (2) Tongue cut in scion; (3) Side cut including tongue in the seedling stock; (4) Stock and scion placed together; and (5) The union tied firmly with raffia, ready for a thin coat of paraffin over the surface of the union and entire surface of the scion.

the fruit, carefully clipping the edges of the husk so that the kernel may be removed without injury. The seed, when freshly removed from the fruit, is slippery and hard to handle. This condition may be remedied by rolling the seed in coral sand. The clipping is probably best done with the ordinary hand pruning shears. (Fig. 2, h.)

Mango seedlings usually graft or bud most easily when they are from 9 to 15 months old. The nature of the graftwood varies considerably in different varieties of mangoes and at different seasons. In most localities of the Territory of Hawaii, it is in the best condition for grafting during the months from December to February, a period when growth is active before blossom time. The best wood consists of the thrifty terminal growth. Sometimes when grafting material is scarce, a second cut, that is, 2-year-old wood, may be used, but the buds are dormant and the growth activity is generally slow. Scionwood should be healthy, clean, plump and firm, and should measure about ⅜ inch in diameter. (Fig. 1, c and Fig. 4.) It is of best quality when cut about one day before it is to be used; packed in damp sphagnum moss, and wrapped in oiled paper. Stored in a moderately cool place, it may be kept 6 or 8 days without serious deterioration. For grafting, such scionwood should be 5 or 6 inches long so that the basal end may be again cut to expose fresh wood at the time grafting is done. The leaves should be removed with a clean sharp knife or pruning shears, and only the stump of the petioles about ⅛ inch long should be left. Care should be taken to avoid injury of the buds in the axils.

In the side-tongue method of grafting, the terminal buds of the scions or of the seedlings need not be in a flush condition as is often desirable in some other kinds of graftwood. The side-tongue graft is made as described under that heading, with practically no differences in the operation or care of the plant after the work has been done.

LITCHI AND LUNGAN PROPAGATION

The litchi and lungan, which are closely related botanically, are rapidly increasing in favor in Hawaii. Both are of comparatively easy culture. Seedlings are easily raised, but are subject to considerable variation, particularly as to their fruiting habits and quality of fruit. The leading obstacle in

getting these fruits into cultivation is the difficulty of getting nursery stock of standard varieties, which of course requires vegetative methods of propagation. Experiments in producing such stock have been in progress at the Hawaii Experiment Station for some years, and a method of grafting has been worked out, which gives a fair percentage of success. These experiments, however, are being continued and the progress is very encouraging. The Station method consists in grafting one-year-old nursery stock of litchi with scions of good variety as *Kwai mi* or *No mi ts'z*. There would no doubt be a great demand in Hawaii for the fruit even if a considerable amount were grown commercially; any surplus above the amount of fresh fruit consumed could be preserved.

The Station's experiments in grafting litchi seedlings show that from 10 to 20 per cent success may be obtained. The method employed with litchi seedling nursery stock of 10 months to one year old is the side-tongue graft, as described under that heading. (Figs. 1 and 5.) It is believed, however, that a more resistant rootstock may be used and in a part of of the Station's experiments, seedling lungans are being used with the hopes of finding a method of uniting scions of good varieties of litchi with them. If the number of successful grafts amounts to 60 per cent or more, the method would no doubt be far superior to the old method of air-layering, which is difficult and slow in producing trees for commercial planting.

Where only a few trees of good varieties are wanted, vegetative propagation by air-layering (also called mossing or marcottage) is a good method to employ. Air-layering requires from 4 to 8 months to develop sufficient roots to sustain life when the branch is cut from the parent tree. It has been found that November is the best time of the year for beginning of air-layering of litchi at the Hawaii Experiment Station. While this form of propagation is in progress, it is necessary to water at least once or twice a week. Frequent inspection is also necessary so that the attacks of ants and other enemies may be prevented. Branches of different sizes may be air-layered, but with certain modifications for the small branches as compared with the method used for the large branches.

Small branches, 12 to 18 in number, may be taken dur-

ing a year from a vigorous 18- to 25-year old tree without serious injury to its growth. In the top of a litchi tree of desirable variety, select branches about 2 feet in length to be used for air-layering. Each terminal should have a stem diameter of ½ to ⅝ inch where roots are to be formed. At this point girdle the stem, removing a piece of bark about 1 inch wide, and allow the wood to remain exposed to the air for

FIGURE 5.—Grafting the litchi and its near relative the lungan. Grafting affords the possibility of propagating a larger number of young trees than by the air-layering method.

about 2 days to dry the sap and to start healing without decay. At the end of the drying period the wound should be surrounded with a small specially made box of redwood lumber ½ inch in thickness and having dimensions of about 3 inches by 3 inches by 6 inches. The two sections of the box should vary in size so that one-half may telescope over the other,—both ends of each half being deeply notched to give space for the box to be placed about the branch, one end above the girdled wound and the other below. Each half of the box, which holds about ½ pint, is packed with sphagnum moss. No other material need be added, and the two halves placed

tightly together around the stem about the wound and tied firmly together with a piece of copper or galvanized wire. The moss is then thoroughly soaked with water, which is poured into it at the opening formed by the notches surrounding the stem above the wound.

The time for removal from the branch can usually be determined, without opening the box, by the appearance of a few root ends at the seams or notches below. To remove the rooted branch from the tree, cut it off just below the box with a pruning saw. The box is then removed and the rooted air-layer, including the moss, planted in a container of rich soil, care being taken to avoid disturbing the roots in the mass of moss. The container, preferably an earthen pot, should be of sufficient size for the young tree to make several months' growth under special care before transplanting it to permanent place in the orchard. For the first few weeks the plants should remain in partial shade and be sheltered from the wind. The air-layering boxes, which are easily made, may be painted on the outside and saved for future use.

Large branches usually require more time for air-layering. They have the advantage, however, of being larger trees when permanently planted. The work of air-layering large branches is much the same as for small branches described above except that a larger marcottage box is necessary, the size depending on the size of branch selected. Sometimes 5-gallon tin containers are cut open and brought together around the mass of moss in the place of the wooden box, but they are more difficult to maintain and do not form as good a protection. When large branches are air-layered only a few can be taken from a tree in the course of a year.